FIELD PERMEABILITY TESTS

BOB'S HOME SERVICE

INTRODUCTION AND BACKGROUND

Three field permeability tests and three laboratory permeability tests were performed by Woodward-Clyde Consultants (WCC) during the period between August 30, 1983 and September 26, 1983 at the request of Love, Lacks, McMahon & Paule.

Two types of field permeability tests were conducted in the monitoring wells at Bob's Home Service (BHS). A non-intrusive slug test was performed in monitoring well K2(OX) (see Figure 1). Well inflow tests were conducted in monitoring wells K3(80) and K4(80). The coefficient of permeability was also calculated for wells K2(OX) and K5(80) from well recovery data contained in Appendix F of the permit application.

The WCC laboratory permeability tests were performed on samples of the unoxidized glacial till to obtain more accurate values of the coefficients of permeability. The WCC laboratory permeability tests were performed in triaxial compression devices with backpressure saturation, which is the most accurate laboratory method to evaluate the coefficient of permeability (Zimmie et al 1981). The results of the permeability tests are summarized on Table 1.

The purpose of the field permeability tests was to evaluate the coefficient of permeability (hydraulic conductivity) of the oxidized glacial till and the unoxidized glacial till at the BHS site. A typical generalized geologic cross section of the BHS site is shown in Figure 2. A zone of perched water, which varies in thickness from 5 to about 20 feet, is located at the interface between the oxidized and unoxidized glacial tills. Well K2(OX) is screened in the interface zone. Wells K3(80), K4(80), and K5(80) are screened in the unoxidized glacial till below the oxidized glacial till and above the sand aquifer. The sand filter pack for monitoring well K5(80) may extend into the oxidized zone so the coefficient of permeability measured in a field permeability test may be an average value of both the oxidized and unoxidized glacial tills.

Previous field permeability tests were performed in both the oxidized and unoxidized glacial tills by Dan E. Klockow & Associates (DEK). The horizontal field coefficient of permeability was measured in wells K1(OX), K1(80), K2(80), K3(80), and K1(SA) using a pressure test method. Due to the high pressures which were used, it is likely that the values of the coefficient of permeability which were calculated from the tests were higher than the in-situ coefficient of permeability. The results of the pressure tests are summarized in Table 1.

Laboratory permeability tests were performed on soil samples from both the oxidized and unoxidized glacial tills. The Missouri Department of Natural Resources (MDNR) performed falling head permeability tests on four samples. Coefficient of permeability values were also calculated from consolidation tests performed by DEK. The values of coefficient of permeability determined by the laboratory tests are summarized in Table 1.

METHODOLOGY

Slug Test

A non-intrusive slug test was performed in well K2(OX) using a down-hole head measurement device (DHHMD) developed by WCC in accordance with the procedure outlined in Bower and Rice (1976). A schematic of the DHHMD is shown in Figure 3.

The slug test was performed by lowering a sensitive differential pressure transducer to a specified depth in the water column of a well. The height of water in the well was then raised suddenly by submerging a "slug" or cylinder of known volume into the well. The change in height ~~in volts~~ was recorded at incremental times of 0.1, 0.5, 1.0, 2.0, 5.0, 8.0, 15, 30, 60, 140 and 880 minutes from the output of the digital volt meter. A continuous readout of the test was provided by the strip-chart recorder. However, the resolution of the strip-chart recorder was much less than the resolution of the output from the digital volt meter.

Well Inflow Test

The well inflow tests were performed and analyzed following the methodology outlined in Hvorslev (1951). Well inflow tests were performed in monitoring wells K3(80) and K4(80), which were completed in the unoxidized glacial till. These two wells contained no free water at the time of the test.

The wells were filled with potable water from the Wright City water supply to a height approximately 5 to 15 feet above the bottom of the well. The change in height of the water levels in the wells was measured at elapsed times of approximately 10, 20 and 30 minutes and then daily for about two weeks using a Soil Test water level indicator.

Well Outflow Test

The well outflow evaluation was performed using well recovery data contained in the permit application. The data were analyzed using the methodology outlined in Hvorslev (1951) for well inflow and well outflow tests. After the installation of wells K2(OX) and K5(80), the water level in the wells slowly rose to an equilibrium position. The depth to water in each of the wells was measured two to three times per week for the six to eight week period until the equilibrium water level was reached. The change in water level with time resulting from the installation of the well is very similar to a well outflow test in which water is removed from a well and the recovery in water level in the well is measured as a function of time. The data from the well recovery after installation were treated as a well outflow test.

RESULTS

Slug Tests

The data from the slug test performed in monitoring well K2(OX) was analyzed using the procedure presented in Bower and Rice (1976). The theory and equations were developed based on a modified form of the Thiem equation:

$$Q = 2 \quad KL\left[\frac{y}{Ln\ (Re/r_w)}\right]$$

where Q is the flow rate (length³/time), K is the hydraulic conductivity (length/time), L is the length of the well screen, y is the vertical distance between the equilibrium water level and the water level in the well at a given time after the slug has been placed in the well, Re is the effective radius over which the changes in head is dissipated, and r_w is the radius of the well boring.

The results of the calculations from the slug test data for well K2(OX) indicates that the coefficient of permeability varies between about 5×10^{-8} and 2×10^{-7} cm/sec.

Inflow and Outflow Tests

The inflow and outflow test data from wells K3(80), K4(80), K5(80), and K2(OX) were analyzed using the equation for flow through a uniform soil presented in Hvorslev (1951). For the condition of variable head (rising or falling), the hydraulic conductivity may be calculated using the following equation:

$$K = \left[\frac{d^2 \, Ln\left(\frac{2mL}{D}\right)}{8L(t_2-t)}\right] Ln\left(\frac{H_1}{H_2}\right) \quad \text{for} \quad \frac{mL}{D} > 4$$

where K is the hydraulic conductivity (length/time), d is the diameter of the well riser pipe, m is the square root of the ratio of the horizontal to vertical hydraulic conductivity, L is the length of the well screen, D is the diameter of the well screen, H_1 is the height of the water column at time t, and H_2 is the height of the water column at time t_2.

Since the soil surrounding wells K3(80) and K4(80) was unsaturated prior to performing the test, the coefficient of permeability has been calculated using the Hvorslev equation to ~~gives~~ give an estimate of the order of magnitude of the in-situ hydraulic conductivity.

The range of values of hydraulic conductivity calculated using the Hvorslev equation are summarized in Table 2.

CONCLUSIONS

Based on a review of the field permeability data, the methodology of the field permeability tests, and the laboratory test data from MDNR and DEK, the primary conclusions are as follow:

1. Based on the slug test and well outflow test data, the coefficient of horizontal permeability of the oxidized zone appears to be in the range of approximately 1×10^{-8} to 2×10^{-7}.
2. Based on laboratory and field permeability tests, the coefficient of permeability of the unoxidized zone varies from approximately 5×10^{-9} to 5×10^{-8} cm/sec.
3. Although the pressure tests conducted by DEK were performed using a recognized procedure, the measured values of the coefficient of permeability were higher than exists in situ due to the high pressures which were used. The high pressure~~s~~ may have induced leakage around the seal and may have hydraulically fractured the soil or opened existing joints or cracks, thus, giving high values of the coefficient of permeability.
4. There is generally good agreement between data from the unoxidized till obtained using all of the test methods. The slug tests and inflow and outflow tests yield results which are about

equal to the falling head permeability tests and are between the values obtained from the consolidation tests and the field pressure tests.

REFERENCES

Bower, H. and R. C. Rice. (1976) "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells," Water Resources Research, Vol. 12, No. 3.

Hvorslev, M. J. (1951). "Time Lag and Soil Permeability in Ground Water Measurements," Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, Bulletin 36, 50 pp.

TABLE 1
HYDRAULIC CONDUCTIVITY CALCULATED FROM
PREVIOUS PERMEABILITY TEST DATA

Test Performed By	Sample Number	Test Type	Sample Location	Oxidized Coefficient of Permeability (cm/sec)	Unoxidized Coefficient of Permeability (cm/sec)
MDNR	BHS I	Lab, F. H.[1]	Test Pit	1.6×10^{-8}	
MDNR	BHS II	Lab, F. H.	Test Pit	1.1×10^{-8}	
MDNR	BHS III	Lab, F. H.	Test Pit	8.4×10^{-6}	
MDNR	K6	Lab, F. H.	Well K6		4.9×10^{-8}
DEK	1	Consol[2]	Well K1	4×10^{-9} to 2×10^{-8}	
DEK	K1	Consol	Well K1		1.1 to 1.4×10^{-8}
DEK	K2	Consol	Well K2		4×10^{-9} to 6×10^{-8}
DEK	K3	Consol	Well K3	4×10^{-9} to 2×10^{-8}	
DEK	K3	Consol	Well K3		9×10^{-9} to 2×10^{-8}
DEK	K4	Consol	Well K4		3×10^{-9} to 5×10^{-9}
DEK	K5	Consol	Well K5		5×10^{-9} to 1×10^{-8}
DEK	-	Pressure Test[3]	K1(OX)	2×10^{-6} to 1×10^{-5}	
DEK		Pressure Test	K1(80)		3×10^{-7} to 9×10^{-7}
DEK		Pressure Test	K2(80)		9×10^{-7} to 3×10^{-6}
DEK		Pressure Test	K3(80)		1×10^{-6}

[1] - Laboratory Falling Head Permeability Test
[2] - Laboratory Consolidation Test
[3] - Field Pressure Test

TABLE 2

HYDRAULIC CONDUCTIVITY BY
FIELD PERMEABILITY TESTS

Well Number	Type of Test	Hydraulic Conductivity (cm/sec)
K2(OX)	Slug	5×10^{-8} to 2×10^{-7}
K2(OX)	Well Outflow	1 to 2×10^{-8}
K3(80)	Well Inflow *	1 to 2×10^{-8}
K4(80)	Well Inflow *	5 to 8×10^{-9}
K5(80)	Well Outflow	1 to 5×10^{-8}

*Note: Tests performed in partially saturated soil.

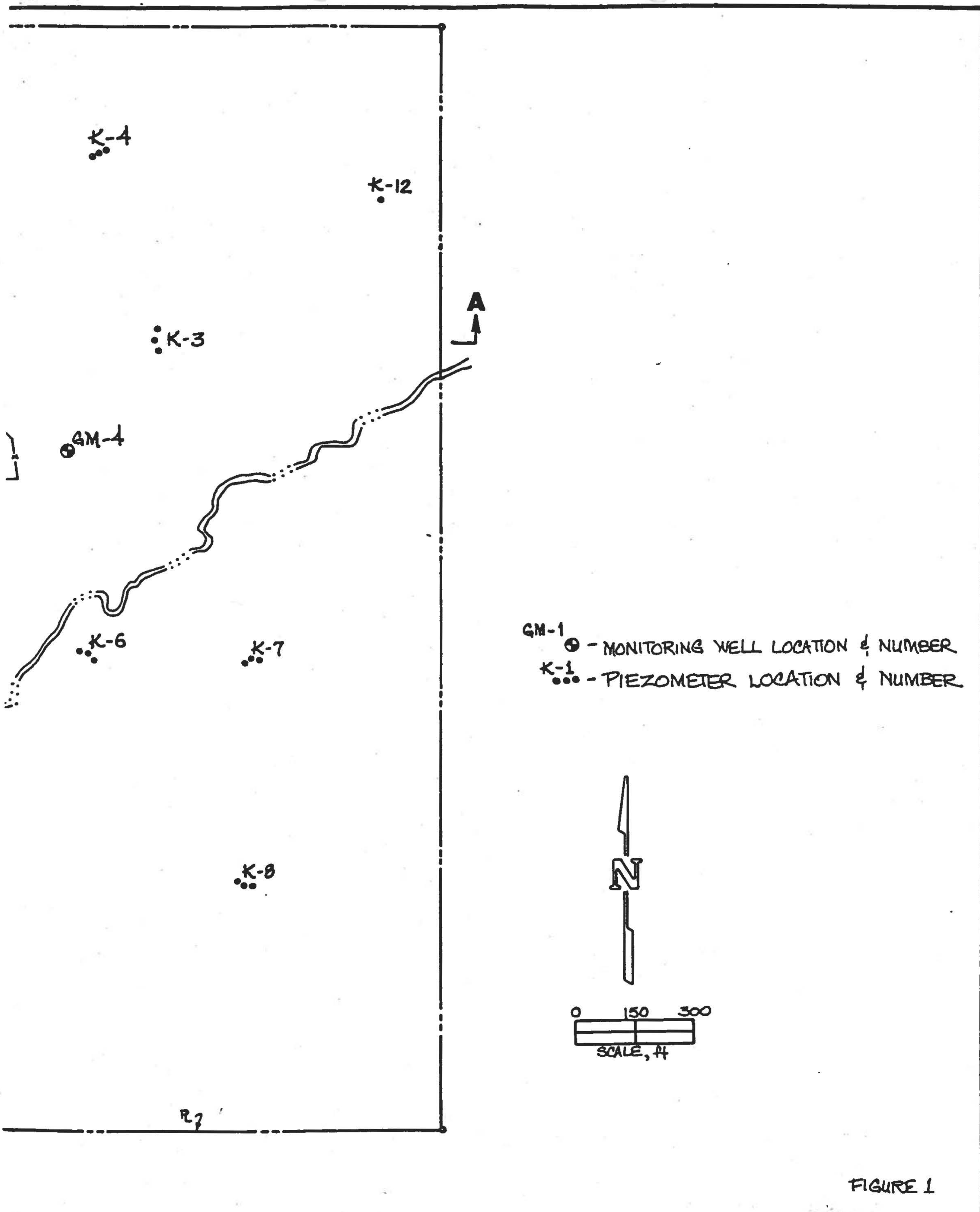
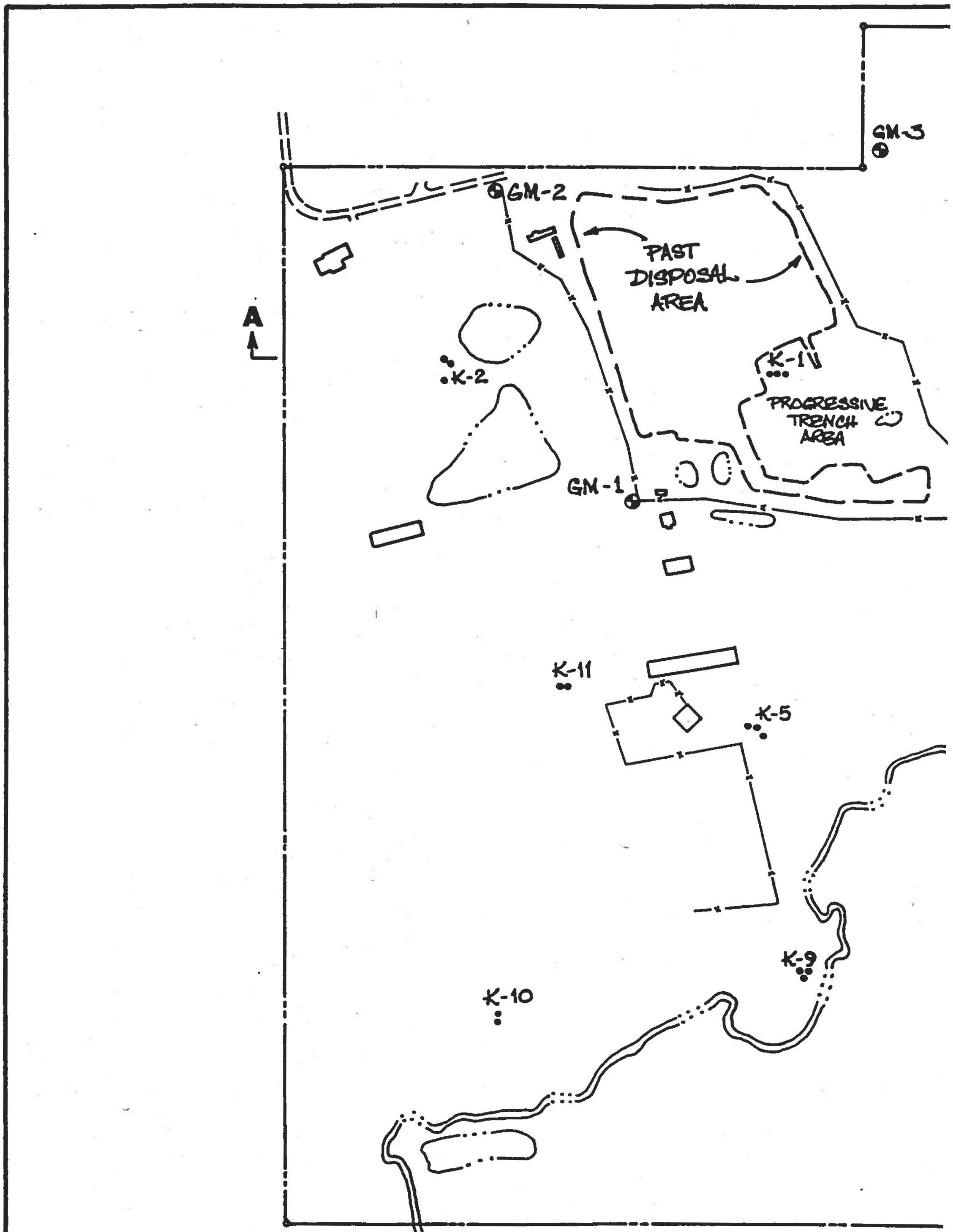

K-4
K-12
A
K-3
GM-4
K-6
K-7
K-8
GM-1
- MONITORING WELL LOCATION & NUMBER
K-1
- PIEZOMETER LOCATION & NUMBER
N
0
150
300
SCALE, ft

FIGURE 1



WCC 13C051
27 SEPT 83 KM

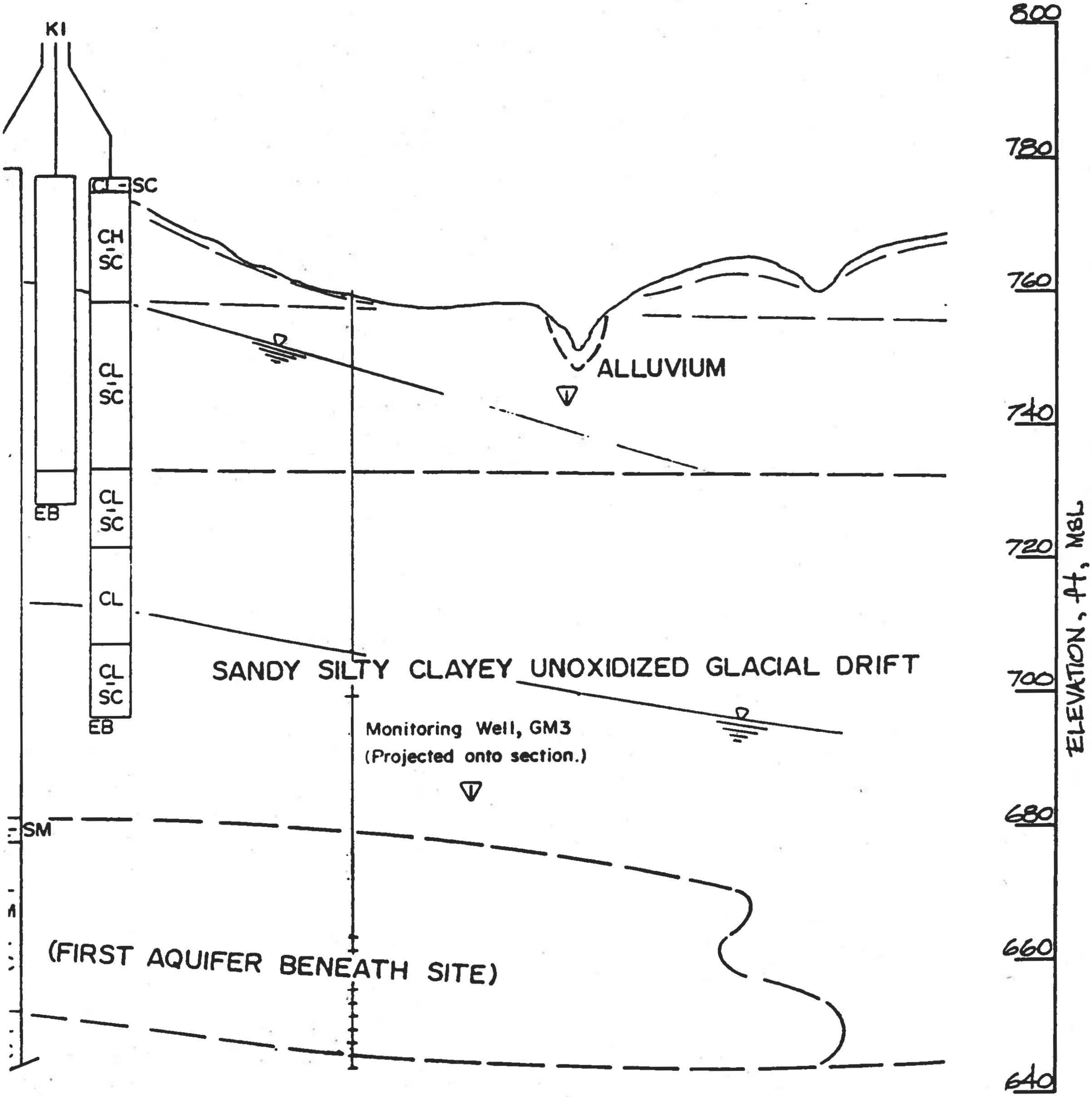
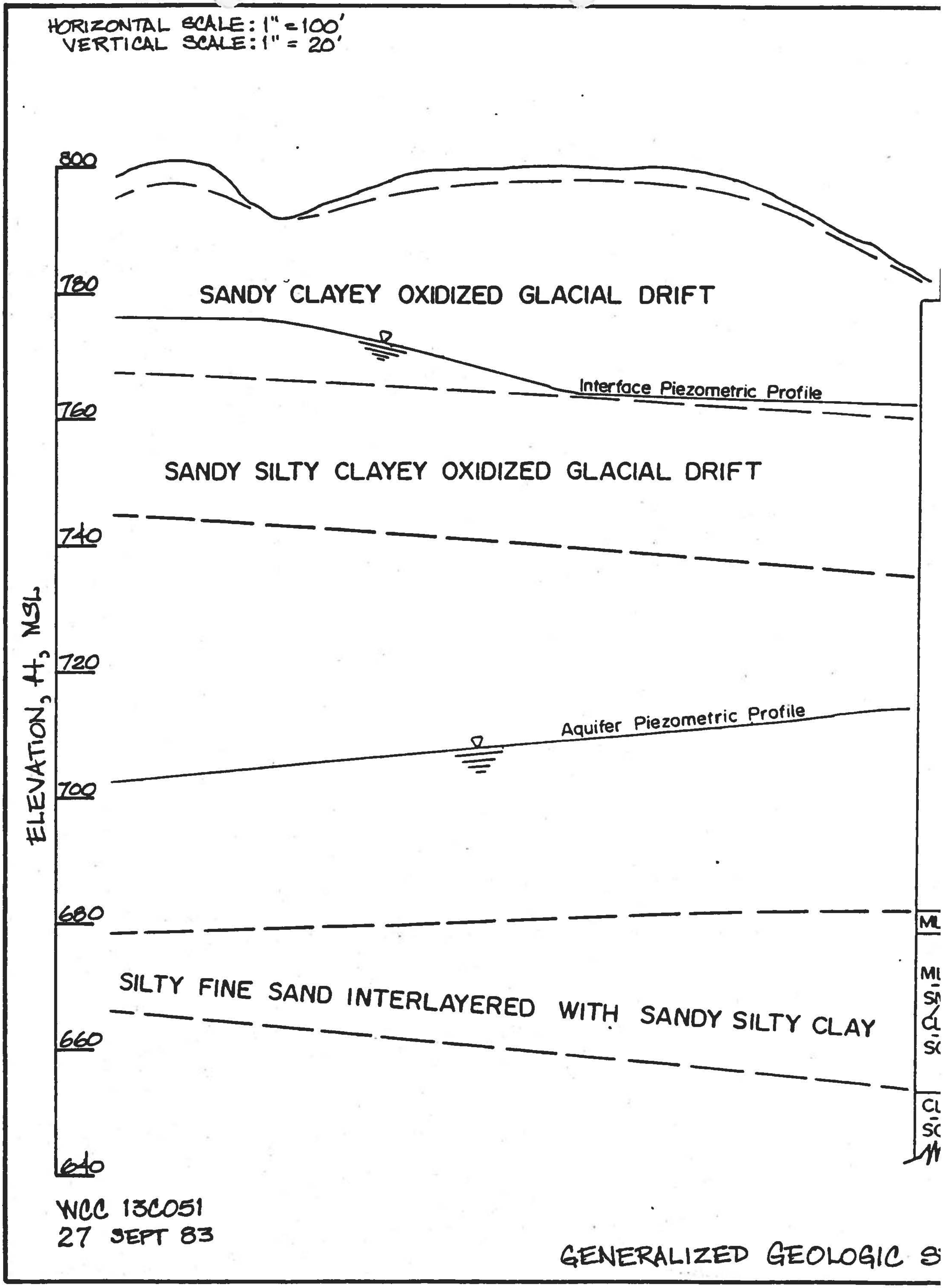
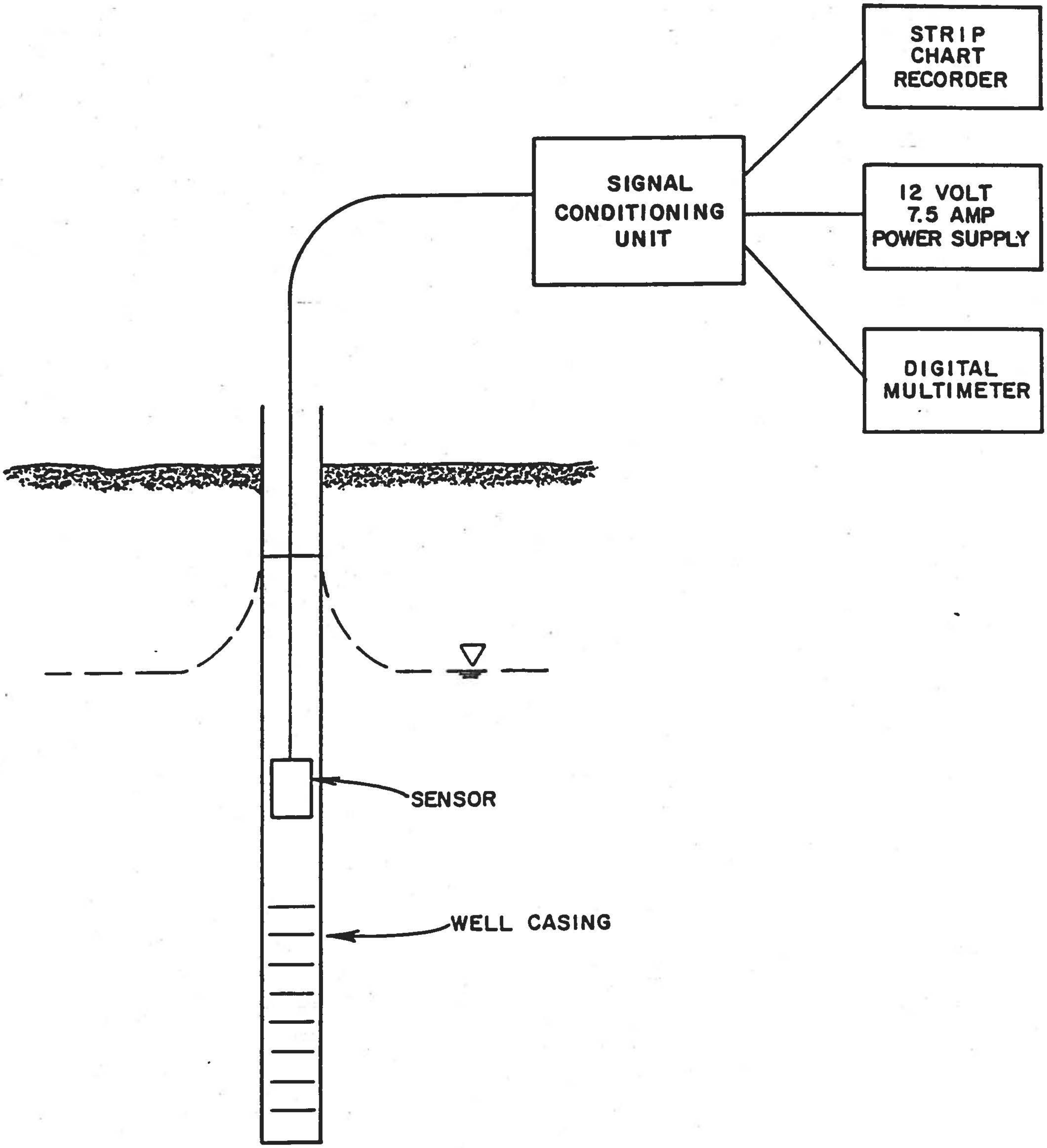


FIGURE 2

ECTION A-A'



HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 20'
800
780
760
740
720
700
680
660
640
ELEVATION, ft, MSL
SANDY CLAYEY OXIDIZED GLACIAL DRIFT
Interface Piezometric Profile
SANDY SILTY CLAYEY OXIDIZED GLACIAL DRIFT
Aquifer Piezometric Profile
SILTY FINE SAND INTERLAYERED WITH SANDY SILTY CLAY
ML
WCC 13C051
27 SEPT 83
GENERALIZED GEOLOGIC S



DOWNHOLE HEAD MEASUREMENT DEVICE (DHHMD) SCHEMATIC

FIGURE 3